Research Proposal of the Thesis Entitled

Enhanced Wireless Sensor Network Lifetime with Optimized Multi-hop Clustering in LEACH Protocol Using Reinforcement Learning and Whale Optimization Algorithm

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By

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1. Introduction:

In recent era, various areas such as environmental monitoring, military surveillance, digitally controlled agriculture, and industrial automation are revolutionized due to Wireless Sensor Network. WSN is made up of numerous sensor nodes deployed across specific areas for receiving data and transmitting data, basically powered by limited, non-refillable sources of energy cells. Thus, improving lifespan of WSN, with efficient end-to-end **data transfer** remains a critical design challenge [4, 15]

The **LEACH (Low-Energy Adaptive Clustering Hierarchy)** protocol is a traditional routing method widely used for its foundational energy-efficient capacity. [17]. But conventional LEACH causes remarkable drawbacks, such as random selection of cluster Head and single-hop Communication, which causes inefficient energy utilization and premature node failures, especially in larger networks [5, 6].

To deal with these issues, the proposed study suggested a hybrid protocol integrating the Whale Optimization Algorithm (WOA) for optimum CH selection and Reinforcement Learning (RL) for adaptive and intelligent routing. WOA is used to improve optimization of multi-parameter problems in WSNs, especially in cluster head selection [30, 28], while Reinforcement Learning introduces adaptability and dynamic decision making that correspondence to fluctuating network states [14, 31]. These improvement leads to increase **energy efficiency**, extend **network lifetime**, and increase **packet delivery reliability** within WSNs.

2. Problem Statement:

- Conventional LEACH-based WSNs encounter significant challenges, which reduce its longevity and overall performance.
- In Wireless sensor network random Cluster Heads (CHs) selection process results in imbalanced consumption of energy throughout the network and can leads to early failure of nodes.
- Single-hop communication between Cluster Heads and the Base Station is followed by conventional LEACH, which results in increased energy consumption, mostly in larger network deployments.
- Improvements in conventional LEACH lead to lack of dynamically learning capacity or smart real-time network conditions adaptability.

  The proposed research directly deals with this constraint by embedding WOA and RL into the LEACH protocol, aiming to develop a smart, energy-optimized routing framework, which is dynamically adapt network fluctuation condition with eventually increase in overall Wireless Sensor Network's functional lifetime.

3. Aim

The main aim of this research is to increase Network functional lifespan and hence performance of the wireless sensor network. By developing smart and energy-aware LEACH protocol, that follows optimized multihop cluster head selection using whale optimization Algorithm (WOA) and integrates adaptability via Reinforcement Learning (RL).

4. Objectives

Objectives listed below are considered to obtain above stated aim.

1. **Create and Execute:** Adaption of whale optimization algorithm is to select most appropriate Cluster Head, by keeping into account parameters like proximity, excess energy and node density.
2. **Reinforcement Learning** mechanism is integrated to consider adaptability and optimized energy efficient multi-hop routing inside the wireless sensor network.
3. **Examine** the realization of the proposed whale optimization algorithm embedded LEACH and Reinforcement Learning based LEACH protocols individually and perform a comparison analysis with conventional LEACH protocol.
4. **Analysis** of performance metrics of Wireless sensor network such as network lifetime, energy consumption, packet delivery ratio (PDR) , throughput, under different simulation parameters.

5. Literature Review

A detailed review of existing literature highlights the different approaches to improve WSN performance, at the same time it explains the gaps, which could intended to address in proposed research.

Sr. No.	Year	Authors	Methodology Used	Key Findings	Gaps Identified
	2024	Hiremath V.et al.	Multi-Hop LEACH	515% increase in WSN Lifetime	WOA and RL not used
2	2023	Wang Z. et al.	Enhanced Pelican Optimization algorithm for CH	Cluster Head selection Optimization.	Single Hop Communication only
3	2023	Singh N. T. et al.	Clustering in LEACH	Improved Lifetime	Static selection of CH
4	Feb 2022	Jagan G. C. et al.	CH selection using electrostatic discharge algorithm	Routs shorten	Gaps not cleared
5	2022	Yao Y. et al.	Archimedes	Enhanced Energy	Absence of

			optimization algorithm	Efficiency	Heterogeneous network support
6	2021	Punithavathi R. et al.	BWO-IACO (Black Widow & Ant Colony Optimization)	Considers node centrality/distance.	Overlooks data aggregation energy.
7	2021	Kaur G. et al.	Deep RL routing	Prevented early failure	Not integrated with CH optimization
8	2021	Senthil G. A. et al.	PSO-LSA (Lightning Search & Particle Swarm Optimization)	Efficient CH selection/path discovery.	Overemphasizes orphan node handling.
9	2020	Vinitha A. et al.	C-SSA (Cat Swarm & Salp Swarm Algorithm)	Reduces latency/energy (multi-hop).	Large-scale effectiveness underexplored.
10	2019	Khalid Haseeb et al.	Intrusion Detection, Optimized Routing, Adaptive Routing	Integrated intrusion detection, adaptive routing for secure, long-lasting WSNs.	CH selection lacked detailed optimization, potentially limiting energy balance.
11	Jan 2000	Heinzelman W. R. et al.	LEACH	Widely recognized clustering.	Energy imbalance, CH overload.

6. Techniques Used

- **WOA (Whale Optimization Algorithm):** A humpback whales inspired bubble-net feeding strategy also known as metaheuristic optimization, particularly effective for complex optimization problems such as optimal CH selection.
- **Reinforcement Learning (Q-Learning):** An adaptive learning paradigm that enables dynamic, feedback-driven decision-making processes crucial for best optimal routing paths in conditions such as real-time network.
- **Simulation Environment:** A proposed protocols will be evaluated using simulation tools such as MATLAB or NS-3.

7. Methodology

The proposed research will follow a structured methodology to design, implement, and evaluate the enhanced LEACH protocol.

Step 1: Network Initialization:

- Deploy 100–200 sensor nodes randomly within a defined two-dimensional area.
- Specify the location of the Base Station (BS).

- Assign an initial level of energy to each sensor node.

Step 2: Selection process of Cluster Head (CH):

- **WOA-based Selection:** The Whale Optimization Algorithm will be applied to select optimal CHs. The fitness function for WOA will consider multiple components like excess energy, proximity to the Base station and density of node within potential cluster areas.
- **RL-based Selection:** Each potential CH will utilize Reinforcement Learning, specifically Q-learning, to update its Q-table. These updates will be based on elements like level of energy and the success rate of previous attempts of routing, allowing for adaptive CH selection.

Step 3: Multi-hop Routing:

- Cluster Heads (CHs) will forward to the Base Station (BS) aggregate data not directly, but through optimal CHs, establishing multi-hop communication paths.
- These multi-hop paths will be dynamically determined and optimized using the learned policies from the Reinforcement Learning component, aiming for energy efficiency.

Step 4: Transmission of Data & Aggregation:

- Each cluster's sensor nodes will transmit their data collected, to their respective Cluster Heads. The received data will then aggregated by CHs for removing redundancy, thereby minimizing the volume of transmitted data and conserving energy.
- Aggregated data will be forwarded along the RL-optimized multi-hop routes to the Base Station.

Step 5: Performance Evaluation:

- The proposed protocols' (WOA integrated LEACH and RL based LEACH) performance will be evaluated against traditional LEACH using key metrics.

Key Metrics include:

- The network Total energy consumption
- Number of active nodes over time.
- Number of inactive nodes over time.
- Network throughput (data successfully delivered).
- Packet Success Ratio (PSR).

8. Relative Assessment

- A **Relative Assessment** of the proposed protocols against the traditional LEACH protocol will be carried out to demonstrate the potential for significant performance improvements.
- The results will indicate that the RL-based model exhibit superior performance in case of energy conservation and reliability when compared with LEACH and WOA-LEACH. This

will highlight the effectiveness of adaptive learning mechanisms in optimizing routing within WSNs.

9. References

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